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REPORT 26-03-R-009

COORDINATION OF OPERATIONS FOR CENTRIFUGE QUALITY CONTROL

(PHASE 3C)

FINAL TECHNICAL REPORT

by

A N Schofield and R S Steedman

10 January 1995

United States Army

EUROPEAN RESEARCH OFFICE OF THE U.S. ARMY

London England

CONTRACT NUMBER DAJA45-93-C-0021

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Contract No.: DAJA45-93-C-0021

Title of Proposal: Phase 3C - Coordination of operations for centrifuge quality control

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A N Schofield R S Steedman 10 January 1995

SUMMARY

ANS&A Associates have held extensive discussions with each of the participating laboratories during the period of research to start to define and to prepare for the initial research experimentation on the WES centrifuge. Briefings on the principles of centrifuge modelling have been given and round table discussions have led to the development of ideas for applications of the centrifuge which will benefit future research programmes. In all fields novel applications of physical modelling have been identified using the centrifuge and these are expected to lead to unique experiments and important new discoveries. In some fields the opportunities afforded by the ability to change gravity have been hard to identify. In other fields, applications and potential future sources of funding for experimental programmes have been easily identified.

The report describes progress with each of the Laboratories in developing their ideas and objectives for initial research work using the centrifuge. The close liason with each of the Laboratories has had important benefits for the detailed design and development of equipment and appurtenances, being carried out in parallel by ANS&A Associates in Cambridge.

ANS&A Associates have also visited France to discuss with Acutronic engineers progress with the manufacture of the Acutronic 684-1 centrifuge. The proposed Acutronic Acceptance Test Plan has been analysed in detail and it is recommended that this Plan be accepted subject to careful interpretation and rigorous implementation. Control of operations during the initial phase following assembly is regarded as critical to the safe commissioning of the facility and it is recommended that the Acceptance Test Plan is regarded as a "blueprint" for operations during this period.

It has been common during the commissioning of other Acutronic centrifuges that Acutronic operate the centrifuge under their sole control during mechanical commissioning until they are ready to carry out the "System Commissioning Test". It is strongly recommended that this procedure *is not followed* for the WES centrifuge. Instead it is recommended that approval to operate *in any part* of the design centrifuge operating envelope *for the first time* should only be given by WES once Acutronic have fully satisfied all aspects of the Acceptance Plan to date to the full satisfaction of the WES COR. Thus the plan for system commissioning will be used to control all operations of the centrifuge prior to the final acceptance and handover to WES. This approach is to minimise the risk of accidental damage during the period of mechanical commissioning. Careful oversight of Acutronic engineers and detailed analysis of instrumental and observational information will be used as a basis for acceptance at all times.

LIST OF KEYWORDS

centrifuge
test
model
capabilities
research
quality
assurance
containment
buildings
equipment
appurtenances
instrumentation
safety

CONTENTS

1.0 DEVELOPMENT OF RESEARCH TOPICS

1.1 RESEARCH BACKGROUND

This report is one of a series of reports prepared by Andrew N Schofield & Associates Ltd (ANS&A) addressing the development and commissioning of new capabilities for physical modeling research at the Waterways Experiment Station (WES), through the acquisition of a powerful centrifuge facility. The research described herein forms Phase 3C of the programme of work first proposed under ANS&A's response (of 17 April 1989) to the WES Broad Agency Announcement (BAA) of December 1988.

Phase 1 of this project, entitled "Safety Factor Analysis for Centrifuge Systems", addressed the specification, Quality Assurance (QA) procedures and safety of operations that would be required to successfully commission a new centrifuge center at WES. In the Final Technical Report under Phase 1 (Contract Number DAJA45-90-C-018), ANS&A (1992), it was recommended that WES should buy the Acutronic 684-1 centrifuge subject to the implementation of QA procedures designed to ensure the swift integration of the new facility into the research activities of WES, Schofield and Steedman (1991).

Phase 2 of this project (Contract number DAJA45-91-C-0012) entitled "Development of a WES Centrifuge" initiated the Quality Assurance process under which ANS&A worked with the Laboratories of the US Army Corps of Engineers through the Centrifuge Coordinating Committee to prepare specifications for appurtenances and data aquisition equipment that would be needed during the commissioning of capabilities. ANS&A's Phase 2 Final Technical Report made specific recommendations concerning the development of appurtenances for initial experiments which would be compatible with the design of the Acutronic 684-1 centrifuge, Schofield and Steedman (1992).

Phase 3A entitled "Centrifuge facility design and development of capabilities" (Contract number DAJA45-91-C-0025) and 3B "Report on Quality Assurance for the WES Centrifuge" (Contract number DAJA45-92-C-0021) addressed the continuing role of ANS&A in providing advice and guidance during the design phase of the WES Centrifuge by Acutronic France SA. ANS&A's Final Technical Report covering Phases 3A and 3B recommended acceptance of the detailed design of the Acutronic 684-1 centrifuge and that the operating envelope of the centrifuge be revised to maximise the potential capability of the facility in the mid-range of operating levels (150-350g), Schofield and Steedman (1993).

This report, describing the research work carried out under Phase 3C, entitled "Coordination of operations for centrifuge quality control" (Contract number DAJA45-93-C-0021), presents recommendations concerning the initial research experimentation on the WES centrifuge and discusses in detail the mechanical commissioning of the centrifuge following its arrival in Vicksburg.

During Phase 3C extensive discussions have been held with each of the participating laboratories. Briefings on the principles of centrifuge modelling have been given and round table discussions have led to the development of ideas for applications of the centrifuge which will benefit future research programmes. In all fields novel applications of physical modelling have been identified using the centrifuge and these are expected to lead to unique experiments and important new discoveries. In some

fields the opportunities afforded by the ability to change gravity have been hard to identify. In other fields, applications and potential future sources of funding for experimental programmes have been easily identified.

Progress in each of the laboratory fields is discussed in detail below (laboratories in alphabetical order).

1.2 COASTAL LABORATORY

Potential applications in coastal engineering which have been discussed include wave run–up on beaches, cyclic pore pressure build–up in dyke foundations or similar coastal defenses and explosive shock waves in shallow harbours. Research experimentation at WES is expected to build on the successful experience of wave modelling on centrifuges in Japan and Cambridge, published by Professor H Sekiguchi and Dr R Phillips. It is envisaged that a wave experiment would use a long box, probably overhanging the centrifuge platform, for operation at low gravities. A paddle would push waves along the box on to the coastal structure. The future extension of this class of research to multi-directional waves was also discussed; however it was concluded that the demonstration of capabilities should address the plane strain problem with a uni–directional wave train.

1.3 COLD REGIONS LABORATORY

Separate visits to CRREL have been made to plan the development of centrifuge modelling capabilities for cold regions applications. Major fields of study include offshore (sea) ice and onshore (frost heave and permafrost) frozen ground.

The development of centrifuge capabilities at WES in cold regions applications will benefit from research programmes which are currently underway at CRREL and at the University of Maryland (an Army Research Office contract under Professor D Goodings). At CRREL a small experimental centrifuge has been developed to gain early experience of model preparation techniques and instrumentation.

Experiments which have been discussed include the penetration of sea ice by vertical load either downwards (aircraft landing) or upwards (submarine emerging); the effects of an ice sheet on rip–rap protected shorelines; interaction between structures (eg piles or pipelines) with frozen ground during freeze/thaw cycles. The selection of experiments will depend largely on progress in the development of model chambers with appropriate control of thermal boundary conditions. It has been found that vortex tubes (driven by compressed air) will provide a basic level of temperature control suitable for maintaining constant temperatures or for slow freeze/thaw cycles; rapid freezing will require the use of a cold gas generator using liquid or frozen CO_2.

1.4 ENVIRONMENTAL LABORATORY

Considerable advances have been made in centrifuge modelling of environmental issues in recent years.

Discussions with the Environmental Laboratory have addressed both the principles and the applications of centrifuge modelling, and have focused on the problem of dredged

waste disposal. Other areas, such as the use of wetlands, large strain consolidation of dredged disposal and contaminant transport processes in multi–phase (unsaturated) soils were also considered.

Capped dredge disposal combines several of these fields, providing a demonstration of capabilities in consolidation, transport processes and cracking/breakthrough of capping layers. Previous experience in centrifuge modelling of environmental problems is largely based on the use of non–hazardous tracers, such as saline solutions, to simulate the contaminant. In the experiments proposed for WES, it is considered that 'true' contaminants should be used to provide novel data for the demonstration of capabilities. These may include heavy metals (cadmium or lead) or dioxins.

Links with academic researchers have been established and early tests using the environmental model chamber in Cambridge have proved successful.

1.5 GEOTECHNICAL LABORATORY

Applications of the centrifuge in geotechnical engineering are many–fold and potential demonstration experiments have been outlined in earlier reports and in ANS&A's initial response to the BAA in April 1989. There are a number of important capabilities which require to be demonstrated, first of which is the capability to create a site with pre–defined conditions, such as a given profile of overconsolidation ratio with depth, sand models of a given void ratio, or layered models. The penetrometer and consolidometer supplied under parallel research work will provide essential tools for the preparation and assessment of soil conditions.

Experiments which are envisaged in the geotechnical field have been identified from a list of proposals submitted by individual researchers. Broadly these were classified into several fields: geological processes, geotechnical engineering, pavements, mobility and earthquake engineering. Demonstration experiments are likely to include studies of the failure of silt slopes, aircraft pavement behaviour under heavy multiple wheel loads, earthquake response of embankments on deep foundations and collaboration with Hydraulics Lab on groundwater models.

1.6 HYDRAULICS LABORATORY

The use of scale physical models in hydraulics has been common for many decades and the opportunities presented by the centrifuge to extend the existing range of capabilities have been carefully analysed with experts in the Hydraulics Laboratory. In particular, it is considered that unlike 'conventional' centrifuge modelling, hydraulic modelling on the centrifuge may not be limited to maintaining equivalence of length and gravity scales. Alternative linear scales may be chosen for any given level of centrifuge acceleration. An important opportunity has also been recognised in the ability of the centrifuge to correctly simulate turbulent flow, a problem which cannot be addressed in open channels at 1g. Using an on–board flume, ideally with a recirculating flow system, example problems such as head loss through rock dykes could be studied under turbulent flow conditions.

A second important field for demonstration experiments is in the area of groundwater flow, for which substantial research programmes are already in place. In this case research would study the basic physics of gravity–driven flow processes such as the

'fingering' of immiscible fluids in contaminated ground. Experimental data would be used for the validation of numerical analyses.

1.7 INFORMATION LABORATORY (ITL)

Opportunities for the development of capabilities relevant to ITL relate primarily to the validation of numerical models for complex physical phenomena. In some applications these may involve collaboration with other laboratories.

Projects which have been discussed which are of unique interest to ITL include the modelling of construction processes, for example the development of earth pressure behind retaining walls, or the exploration of fracture mechanisms in mass concrete.

The validation of numerical models is a key role for the centrifuge and is a capability that should be demonstrated during the commissioning period. However the detailed nature of many of the processes being modelled by ITL present particular challenges for the centrifuge and the definition of experiments in this field will require very careful consideration. This will be pursued further in the next phase of the project.

1.8 STRUCTURES LABORATORY

Detailed discussions with Structures have indicated a wide range of experiments of interest in blast loading and weapons effects for the demonstration of capabilities.

Field problems principally concern the detonation of charges in rock, the stability of underground magazines or failure of tunnels. These experiments would require the use of simulated rock material, which may be homogeneous or built using a predetermined fracture pattern. Early experiments will be conducted using the blast chambers constructed during Phase 1 of the appurtenance development, to establish their suitability for weapons effects testing.

Cratering in multi–layered soil sites is also an important capability to be demonstrated, which will provide data for the prediction of blast loads or buried structures, and for dynamic terrain modelling. Detailed discussions on instrumentation for blast experiments have concluded that a high speed camera will be necessary to capture the events in detail and that this may need to be mounted in the ceiling of the centrifuge. Other instrumentation will be developed based on past experience of the performance of pore pressure transducers, total stress gauges and accelerometers.

It is clear that Structures Lab will be one of the main users of the centrifuge and will exploit the full range of centrifuge capabilities. The advances in technology for modelling problems in the field of rock mechanics will be particularly important.

1.9 RECORDS OF DISCUSSIONS

Under ANS&A's Quality Plan all meetings are documented and used to provide a record of progress on the project. The meeting notes cover the discussions with each Laboratory on future capabilities and opportunities in some detail and describe meetings in France and the UK relevant to the project; notes appended to this report continue the sequence of meeting notes from the Phase 3A & 3B Final Technical Report and cover the period through to 31 December 1993.

2.0 STAFFING ARRANGEMENTS

Careful consideration has been given to the nature of the staffing for the centrifuge facility needed during operations. Several of these staff will need to be identified and trained well in advance of the centrifuge arrival to ensure full advantage is taken of the process of centrifuge assembly and commissioning. It is recommended that the centrifuge staff includes:

Centrifuge Manager	senior engineer responsible for the safe operation of the facility, controls programming of tests, approves flight plans, assists in conceptual design of experiments, manages junior staff, responsible for external relations, organises training; authorised engineer.
Mechanical Engineer	responsible for design and operation of appurtenances and interface with Acutronic 684–1; fully familiar with centrifuge design and assembly, oversees maintenance and all mechanical/hydraulic services; authorised engineer.
Electrical/Electronic Engineer	responsible for electrical services, control and data acquisition systems, instrumentation and wiring of packages, safety management systems (interlocks, CCTV), central arm services, power supplies and shipping stack, software development and control; authorised operator.
Model Technicians	two to three technician staff, skilled in model preparation, fabrication of small components, soil placement, basic instrumentation, wiring and plumbing techniques, laboratory safety, cranage and package handling, material handling and disposal, interpersonal relations. Awareness of centrifuge theory and hazards of operations.

These six staff would be trained to become the centrifuge core team during initial operations and the commissioning of capabilities. The team would be supported by one or two electronic technicians on a part–time basis. As the centre develops, higher level management may be necessary, particularly to provide the external relations, marketing and overall direction of the facility. Such a position will depend on the internal reporting structure determined by WES for the centrifuge center. It may also be advisable to train suitably qualified technicians as authorised operators, to ensure that adequate coverage is available at any time. ANS&A's report on Phase 1 presented a draft operating procedure for the centrifuge, defining the roles of engineer, user and operator. Authorised engineers would also be qualified to act as operators if required.

Full recommendations for the Standard Operating Procedures will be presented in ANS&A's Phase 3D Final Technical Report.

3.0 COMMISSIONING AND ACCEPTANCE OF THE ACUTRONIC 684-1 CENTRIFUGE

The Acceptance Test Plan proposed by Acutronic is based on their earlier experience of centrifuge commissioning in Japan and Canada and it needs to be read in conjunction with their original contract and with the various letters and memoranda relating to their contract. The plan forms a good basis for the control of operations during the mechanical commissioning period provided it is strictly implemented according to the following detailed interpretation.

The Plan must be regarded as the development of an operational envelope for a novel machine. The 684–1 has a platform capability of which Acutronic US (AUS) have no previous experience: it will fly at about 140 metres/sec, which is double the maximum velocity of any previous Acutronic Geotechnical Centrifuge. From previous experience of novel centrifuge commissioning, for example the failure of the large centrifuge at NASA Ames, it is clear that the owner risks loss if the facility is placed in the hands of engineers who run at full speed quickly without strict oversight. Therefore, USAE WES must insist that their permission is given for each advance from page to page of this acceptance test plan.

Because this is a unique machine the "Yes/No" boxes in the Factory Acceptance Test and System Commissioning column of the Acceptance Plan raise questions which do not have a simple answer. For example it is not possible to fully understand the significance of any particular question until the Plan is partially completed. The success or failure of AUS to comply with their contract is to be indicated by ticks in these "Yes/No" boxes. Each box can be filled only by the USAE WES Contracting Officer's Representative (WES–COR) and confirmed by initials and a date.

At first sight it would appear that a Factory Acceptance Test (FAT) involves the transfer of responsibility from Acutronic France to Acutronic US, and the System Commissioning Tests (SCT) involve the transfer of responsibility from AUS to WES. However, WES has paid for and has an interest in all items even before the FAT, and therefore WES must be careful that there is no damage, or loss of the capability to rectify damage, before the centrifuge is installed. The following sections concentrate on the SCT. It is expected that ANS&A personnel will also advise on the FAT in France.

Damage or a failure of any part of the centrifuge during system commissioning must be rectified before a "Yes" can be entered in the appropriate Test Plan box, but no definition of failure is proposed. As a simple example it is proposed to accept the dimensions of the platform on the basis of a Yes/No choice. But in practice the dimensions of the platform are specified to a certain tolerance and this should be specified as the basis of acceptance. This becomes particularly clear when the centrifuge specification is read in conjunction with the centrifuge performance section of the plan. Item II,1,2 provides the opportunity for WES to ensure that there is full documentation, including the promised "Grey Book" with stress calculations, and the promised ANSYS program and calculations on appropriate disks. This item alone will require several months to review before it can be approved and AUS should be advised without delay that items such as this cannot be accepted on the basis of a cursory inspection. They should be advised that a rejection will be entered in this box if WES is unsure that the system as built is safe to operate or is unsure if a part is or is not damaged.

The Acceptance Plan does not specify any gauges and instrumentation and it must be assumed that AUS will have no data to allow the centrifuge performance to be assessed in detail. Quality assurance of all major parts must be achieved not only with the system as built but also at each stage of the development of the operational envelope. For this purpose it may be appropriate for WES to find a sub–contractor to perform non–destructive tests (NDTs) and to measure critical dimensions of all major parts prior to System Commissioning. In order that this activity should not delay System Commissioning it will be useful to examine the detailed timing proposed by AUS. For example if the platform is available for NDT at the FAT stage, the WES contractor could then establish basic parameters such as resonant frequencies, which might be expected to change with the onset of cracking in any weld within the platform structure during early operation. If after any test run a NDT or a measurement shows a significant variation from the pre–test values then that test run cannot be given a "Yes". The WES contractor may need to perform load tests using jacks to confirm an FE analysis of the platform prior to commissioning. FE analysis could also indicate the magnitude of permanent deflection that would indicate failure of weld within the platform. WES may require AUS to operate the centrifuge for test purposes, for example, in a run at low acceleration using the self–weight of the platform to cause elastic deflections for the purpose of the calibration of a WES FE analysis. The testing contractor may fit the central arm services for the purposes of obtaining data in a test run specified by WES, and WES may also require AUS to pause during the commissioning test programme while they evaluate data obtained at that stage of development of the operational envelope.

The performance of all electrical and electronic items, and the possibility of distress in an item during a high–g run will be the concern of WES instrumentation staff, and the WES–COR should ensure their satisfaction before giving acceptance.

The Centrifuge Specification (pages 10–12) is unsatisfactory in a number of ways. For example the Figure II.1 is inaccurate, and AUS do not state how a two tonne load can be uniformly distributed over a circular area of 1.2 m in diameter, and how they can confirm that a total indicated reading (TIR) is no more than a 0.2 mm +/– 1.2 mm departure from platform flatness both under static load and under acceleration of 350g at nominal radius. The static requirement must be achieved before acceptance can be given for III,1,2 and the dynamic requirement at an appropriate g–level in III,3. The verification of vibration and power performance also is not satisfactorily defined, and electrical noise and cross flows of fluid passages will require testing to satisfy the WES–COR.

During development of the operational envelope the SC unbalance testing specified in sections III.3.1.1 to III.3.1.2 can be performed only when the operating envelope reaches the appropriate level (i.e. 40 rpm). Prior to the development of the operating envelope at 100 rpm the WES–COR will decide what are the requirements to be met for smoke, temperature and humidity levels. Also, when the proposed 200 kg and 2000 kg loads are applied (page 19), it will be necessary to confirm that a uniform pressure has been achieved below.

Rate accuracy and stability must be tested at the appropriate stage in III.3.2. Tests involving environmental transport processes may well take two days or longer. In this regard a two hour test cannot be regarded as an acceptable "long–term" test. Instead a true long-term test should be performed of at least 36 hours duration, either by AUS or

by WES, at 280g with a 2 tonne package (or other acceptable load configuration). This test is seen as essential in establishing that no overheating or other problems occur.

In view of the shroud failures that have recently been experienced by Acutronic France, particular attention must be paid to the possible onset of cracking or buckling in flight of the shroud. Particularly in III,3,1.2 the WES–COR may request inspection of the shroud at each incremental increase in the operational envelope.

Under item III,3,2 the WES–COR may find it useful to have an independent speed check. AUS must also specify how they intend to apply the 800 kg load; this load must be fully flexible inducing minimal shear stress on the platform surface. For example, the load may be composed on alternating layers of lead sheet and lubricated rubber sheets.

The long duration test profile item III, 3,5,2 is unsatisfactory. For the reasons previously mentioned a long duration test should last for at least 36 hours during which the chamber temperature and humidity should be monitored.

The meaning of the statement on page 34 is unclear since AUS are in fact responsible for the containment structure and the centrifuge, and cannot disclaim responsibility for any part of the facility.

Delivery of the Acutronic centrifuge includes a large body of documentation on the design, manufacture, quality control (including specifications, material certifications, welding inspections etc), and operation of the centrifuge. Discussion with Acutronic in France has focussed on the completion of the design file, which is regarded as incomplete in several respects. For example details are given of early design approaches but these have been superseded and little explanation is given of the final calculations and numerical analysis. It is essential that these deliverables are competed to the high standards expected from Acutronic and delivered on schedule with the centrifuge. Without this documentation, acceptance of the centrifuge will be delayed.

REFERENCES

Schofield, A.N. and Steedman, R.S. (1992) Development of a WES Centrifuge, Final Technical Report, ANS&A Report 26-02-R-004 for US Army European Research Office, London (Contract No. DAJA45-91-C-0012).

Schofield, A.N. and Steedman, R.S. (1991) Safety Factor Analysis for Centrifuge Systems, Final Technical Report, ANS&A Report 26-01-R-001 for US Army European Research Office, London (Contract No. DAJA45-90-C-018).

Schofield, A.N. and Steedman, R.S. (1993) Design of the WES Centrifuge (Phases 3A & 3B), Final Technical Report, ANS&A Report 26-03-R-006 for US Army European Research Office, London (Contract No. DAJA45-92-C-0021).

APPENDIX A

Records of meetings

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-059
Present:	RSS, RHL, RP, K Davis,	Date:	1 February 93
	H Greer, S Maynord, L Hales	Time:	9 am
		Prepared:	RSS
		Notes:	WES Centrifuge Committee
Subject:	Development of Capabilities		

Centrifuge programme

RHL briefed the Committee on the current status of the centrifuge project. The design had been completed, using high performance steels to meet performance specification. Capability had now increased to around 8.8 tons (US) to around 140g. Costs had escalated due to increase in weight of machine and fabrication costs. Commissioning date now expected to be in February 1995. Acutronic USA will be responsible for the construction of the containment structure and will use the WES AE, Johnson Macadam. Substructure is expected to be completed by October/November 1993.

Centrifuge design

RSS discussed the design of the centrifuge and issues relating to equipment and useability. The design of the platform, supporting straps, hinges and pins, headroom and distance between the booms was noted.

Blast chamber

The conceptual design of the blast chamber was considered. Emphasis was expected to be on large models at lower gravities if necessary, because of weight restrictions. Torospherical lid was not considered essential and it may be preferable to replace this with a simple extension unit. Used with a pressure lid, however, the chamber would have extensive application for sea bed studies or studies requiring increased atmospheric pressure. Analysis of the chamber is to be discussed with the Structures Laboratory.

Hydraulic flow

Options for high flow of up to 2 cubic feet per second (57 kg/sec) were considered. Current approach may be to replace the hydraulic joint with a single passage unit, dispensing with automatic balancing at low g. However there is a considerable impact on the building design including the slope on the floor, adequate drainage, consideration of spray and impact of water on the wall and the difficulty of replacing the hydraulic joint itself in the motor room.

Slip rings

Acutronic's response to ANS&A's proposals, set out in ANS&A's letter to WES dated 2 December, was discussed. An increase in the number of video lines was considered important.

Thermal control/air conditioning

The importance of thermal and humidity control on long duration tests was emphasised. High air flow in the chamber is likely to avoid problems of condensation.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-060
Present:	RP, H Greer, B McCleeve	Date:	1 February 93
		Time:	2 pm
		Prepared:	RSS
		Notes:	WES
Subject:	Data aquisition		

Data aquisition

RP described ANS&A's conceptual data aquisition and test control system (DAS & TC) in detail, and compared it with the LCPC and CUED systems. Copies of the EQUIP-03 1st Interim Report, the CUED junction box user manual, ANS&A's letter to WES of 2 December 1992 and the draft CUED trolley mounted data logger technical manual were presented.

It was emphasised that the initial system was not suitable for high bandwidth signals (>50 kHz). Dr Raphael Franco (WES) has experience in this area, based on data aquisition of projectile embedment into walls.

Power supplies

Single phase supply is 120V 60 Hz to neutral. Two phase supply permits 240V AC. Three phase supply is either 440 or 480V AC between phases.

Fittings

Preferred pipe fittings are NPT for low pressure applications and JIC for high pressure.

Copies:

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-061
Present:	RSS, RHL, RP, PH	Date:	1 February 93
		Time:	pm
		Prepared:	RSS
		Notes:	WES
Subject:	Centrifuge programme		

Costs

The escalation in costs had removed any "cushion" left in the budget, leaving the programme extremely vulnerable to external pressure for economies.

Programme

The building programme was extremely tight. To beat the rains expected in November construction of the entire foundation and substructure would need to be complete by October 1993. Otherwise it would be more cost effective to delay the entire programme until after the winter.

Appurtenances

The appurtenance contracts presently being carried out by ANS&A had to be delivered by 30 September 1993 to a US Government facility in the UK. This deadline cannot be extended.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-062
Present:	RSS, RHL	Date:	1 February 93
		Time:	pm
		Prepared:	RSS
		Notes:	WES
Subject:	Centrifuge specification		

Options for reducing the specification of the centrifuge

Options for reducing the specification of the centrifuge, given the material already purchased and design work already completed, were discussed. These included:

1. Substituting a lower strength steel for the high steel in the platform slab. This would dramatically reduce the payload capacity at higher g;

2. Purchase of a 680 centrifuge, with similar specification to CCORE or LCPC, perhaps using the present motor set, and recovering the scrap value for purchased metal which could not be reused;

3. Termination of the contract.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-063
Present:	RSS, RHL, K Davis, R Welch	Date:	1 February 93
		Time:	pm
		Prepared:	RSS
		Notes:	WES
Subject:	Blast chamber		

Discussed the dynamic loading on the blast chamber from an internal explosive source. Bob Welch will provide time histories of loading on the boundaries of the chamber for use in a dynamic FE analysis. The soil model will be considered to have the attenuation of water, and the density of rock. The dynamic structural analysis will be completed by a member of Robert Hall's group. It was considered that a rubber mat under the chamber would be the best way to remove high frequency shock.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-064
Present:	RP, P Gilbert	Date:	2 February 93
		Time:	9 am
		Prepared:	RSS
		Notes:	WES
Subject:	Centrifuge programme		

Discussed the increase in operating envelope now potentially available for users and appurtenances presently being specified for delivery in September 1993.

Fasteners and pipe fittings

It was noted that although government procurements after December 1992 required metric specifications, in practice American thread forms and pipe fittings still dominate and are preferred. It was agreed that RP and PG would investigate and compare European and American metric threadforms for compatibility.

In the absence of metric pipe fittings, NPT tapered threads are preferred for working pressures of 600 psi.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-065
Present:	RSS, RHL, RP, R Hall, T Bevins	Date:	1, 2 February 93
		Time:	pm, am
		Prepared:	RSS
		Notes:	WES
Subject:	Blast chamber analysis		

This note records meetings held with Robert Hall and Tommy Bevins to discuss the FE analysis of the blast chamber.

It was agreed that a simple axisymmetric model would be used initially, with dimensions specified by RSS (later supplied in a guidance note).

ANSYS is not available in the Structures Laboratory; however it was thought that an ASCII file could be converted "manually" for use with ABAQUS or ADINA.

Contacts at the Information Laboratory would be asked whether ANSYS was available there.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-066
Present:	RSS, RHL, RP, S Maynord	Date:	2 February 93
		Time:	am
		Prepared:	RSS
		Notes:	WES
Subject:	Hydraulic flow		

Hydraulic flow supply

The velocities of flow through a single passage hydraulic joint 90 mm in diameter could be as high as 35 ft/sec. Given these high velocities, and the difficulties of entering and exiting the slip ring stack it is likely that supply on axis would only be possible to around 0.5 - 1 cubic ft/sec.

Hydraulic flow on arm

Three solutions were considered.

1. Orifice pipe, probably 5-6" diameter;

2. Open channel with vent;

3. Closed pipe with plate with holes at the end.

None of these were considered very satisfactory, particularly given the cost and uncertainty over the performance of the supply through the slip ring stack.

Recirculating system

An alternative system would be to construct a recirculating flume, perhaps using a propeller system which would be appropriate for the low head environment required. Given the large carrying capacity of the platform, and the possibility of overhanging the platform at low g with a special frame to support the flume, it was agreed that a recirculating system would be practical and would involve the least development risk. It is likely that a model of such a system could be built and tested on the Cambridge centrifuge.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-067
Present:	RSS, RHL, L Hales	Date:	2 February 93
		Time:	pm
		Prepared:	RSS
		Notes:	WES
Subject:	Coastal applications		

A large range of applications is not perceived at present. Physical modelling of the near shore zone usually involves a large area with small vertical dimensions. Typical lengths of coastline under consideration may vary from hundreds of feet to several miles. The exception may be problems involving foundation stability or beach sand movement, or scour around the end of a structure.

A square 300 m tank could investigate beach movement using an inclined wave generator.

The rock dyke stability problem was considered the most likely at present. Typically around 20 feet high with 2:1 slopes on either side. Structures may be 150 feet wide at the base, with a 20 foot crest width. Wind generated storm waves may have a 10 second period with a 10 foot peak to peak amplitude. Structures are intended to be impermeable on construction but over time the inner core is washed out and the rock rip rap collapses.

1g models of coastal dykes are typically 1/20 scale in tanks around 5 feet wide with run-up of 150 - 300 feet. The model dyke may be around 3.5 feet high with a water depth of 2 feet and a freeboard of 1.5 feet. Seabed depth below the dyke would be typically 1.5 feet. The wave generator would compensate for reflections with a feedback loop.

Waves in deep water have a half wavelength = $5.12\ t^2$; eg. for a 10 second period, the half wavelength is 512 feet. The water may be only 100 -150 feet deep. In shallow water the wavelength decreases. Typical beach slopes may be around 1:50. Field tests woud bring a generator in to around 50 feet depth of water and then emit waves that were appropriate to that environment. Wave periods vary from around 2 seconds to 25 seconds; the upper limit on long period waves may be as much as several minutes.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-068
Present:	See below	Date:	10 February 1993
		Time:	9 am
		Prepared:	RSS
		Notes:	WES
Subject:	Centrifuge and containment structure		

Attendance

R H Ledbetter (WES),
G Hale (WES),
R S Steedman (ANS&A),
P Hadala (WES)
A J Breithaupt (WES),
B Logue (WES),
E Adcock (WES),
D Haulman (WES),
H Greer (WES),
J Perdriat (AFA),
H Voss (AUS),
E Johnson (Johnson Macadam),
J Martin (Johnson Macadam),
R Schulte (Stanley Consultants),
W Walker (Stanley Consultants).

The meeting was chaired by RHL.

INTRODUCTION

Key points made during the introductions were the risk posed by cost escalations, the increased capacity of the centrifuge (1256 g tons), and the new date for commissioning of February 1995.

PH stressed that this was a research effort and there would remain a high risk that further budgetary cutbacks would cut off funding at short notice. There was no guarantee that funding to complete the project would be automatically forthcoming. The contract modifications needed to commence the building construction still had to be completed; this would require close cooperation from everyone to be achieved in a timely manner. RSS extended ANS's apologies for absence due to commitments in Cambridge. RSS noted that ANS&A's goal is the delivery of new research capabilities; the centrifuge and building were an important part of that process but on their own would not suffice in meeting the requirements of the BAA. The final design of the centrifuge, with the potential for increased capacity in the low to mid-range g levels, was very much to be welcomed.

Acutronic noted the good cooperation which had been achieved with ANS&A, the quality of the design and the increase in capabilities that had resulted. Costs were now known very precisely and it was not expected that any further escalation would be necessary. It was agreed that ANS&A's insistence on achieving a factor of safety of 2.7 to the elastic limit had been the right decision and had led to an outstanding and unique machine.

CONTAINMENT STRUCTURE

Excavation for the new containment structure was expected to produce around 11000 cubic yards to be stored during construction. Around 1500 cubic yards would be required in addition to this for backfilling. Storage will be between the existing building and the magazines. The site office will be located in the car park behind the Casagrande building. The location of the centrifuge was agreed. It was noted that construction costs might vary by up to 20% depending on the time of year the work is bid.

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Reference: 25-03-ROM-068 contd.

Modifications to the design include the removal of the sump associated with the high flow water system (which will be provided instead by a recirculating system on board) and the removal of the camera room shown in early sketches.

Access to the roof of the centrifuge will be severely restricted in flight. An airlock door could be provided for access but it was agreed that a simpler solution would be to permit emergency access only at low g by shutting down the fans temporarily (five minutes or so) and not allowing access at all at high g. Equipment should not be located there which required access.

The revised design has minimal consequences for the structural design of the building. The payload has been increased to 8000 kg at 150g without any additional fixed counterweights. The existing six tonne counterweight will accommodate the increase in payload by moving over the full length of the (longer) booms.

The highest frequency of the pressure wave is around 4 Hz. The lowest natural frequency of the containment structure must be at least four times this value because of the strength of the third harmonic. The pressure wave rises steeply in front of the gondola and may drop slightly below atmospheric pressure around mid height on the wall immediately behind the gondola.

Tolerances are critical on the building. The air gap between the gondola and the wall is critical as around 1.2 MW of energy is dissipated in friction by air on the wall. Some centering adjustment (± 5 mm) is possible by Acutronic but not desirable. Concern was expressed over temperature and humidity of air flow. Variable speed fans were recommended by Acutronic to accommodate the range of speeds and climatic conditions. ACTION 1: JP

The walls must be sealed. ACTION 2: EJ

A transformer will be needed on board to provide local voltages on arm. ACTION 3: RSS

Concern was expressed over the availability of parts in future to support the 380V on arm Acutronic supply and general Acutronic 660V power requirements.

The floor of the chamber must have a fall for drains. These should have closable vents in flight but should otherwise be specified as laboratory drains. A collector may be required outside the chamber in future.

Lighting in the centrifuge chamber will be to normal room standard.

It was noted that the outlet air channels in the motor room should be repositioned from early drawings to maintain the same inlet and outlet areas. This would also simplify construction.

It was agreed that one emergency shutdown button will be located in the wall near the large door (a second is available on the centrifuge near the centre).

The regulations will be checked concerning the need for a second exit door from the chamber. This may be necessary in view of the environmental risk. ACTION 4: EJ

Final dimensions of the electrical cabinets will be sent by Acutronic to Johnson Macadam. ACTION 5: JP

The roof camera slot is to be defined but anticipate slot 18" x 18" and around 1 m in length. ACTION 6: RSS

Power supply to be provided above centrifuge chamber. ACTION 7: EJ

Installation of the centrifuge will require a large crane to be brought very close to the chamber. The maximum mass to be lifted in one piece will be 62000 kg. Acutronic will supply names of crane contractors to Johnson Macadam. ACTION 8: HV

Reference: 25-03-ROM-068 contd.

The centrifuge is mounted on four springs which must be correctly aligned and hence strict tolerances have been specified on location and alignment of the four pads. Johnson Macadam will design anchoring solution within local code requirements. JP explained the anchoring methods used satisfactorily in France.

Roof beams should be adequate to suspend the centrifuge for future maintenance. Johnson Macadam have checked that the stiffness of the wall will be adequate for a crane to be brought to within 5 feet. The crane supplier will be expected to decide whether bearing pressures are adequate.

Louvres to be provided by Johnson Macadam. ACTION 9: EJ

Fans and motors to be provided by Acutronic (powered through Acutronic's power system). Drawings to be provided by Acutronic to Johnson Macadam. ACTION 10: JP

The slip ring area has been redesigned: the dimensions of the grid have changed. A support frame for cable trays and cables must be defined from the user slip rings. ACTION 11: RSS

The door will be supplied with the other Acutronic equipment. The dimensions are 2.5 m high by 3 m wide. Door acceptable in principle, subject to checking on forklift access. ACTION 12: RSS

Some differential settlement is to be expected between the Prep Room and the centrifuge chamber. This could be repaired with (for example) an epoxy wedge. Foundation for centrifuge chamber will be assumed to be piled for cost purposes but final decision is needed urgently. Such a decision will depend on the acceptable limits of rotation of the structure (which was quoted as ±1 mm in 1.6 m by Acutronic).

The Prep Room will be fitted with water supplies, sinks and drains, basic power, three phase power, vacuum and air pressure systems. Power supply voltages in Prep Room to be defined. ACTION 13: HG

A crane rail for a 10 ton (US) crane is to be provided (although this may not be necessary if forklift transportation is adopted throughout).

The stairwell drawings will be checked by Acutronic for airflow. The stairwell will be fire rated.

Acutronic will revise the 'Installation Manual' with final dimensions of the skids etc within two weeks. ACTION 14: JP

Signal and power lines will be brought in separate trenches from the control building to the centrifuge. Conduit from slip rings to Prep Room to be provided in addition to slip rings to control room.

The supply for the hydraulic joints to be 10 litres per minute per joint (6 joints total). Six pipes will be needed for the user from the hydraulic joint to the area at the base of the stairwell. Water and high pressure air supply should be available on a manifold. 6 channels to be provided from the base of the stairwell to the Prep Room for other services. ANS&A and Acutronic will specify their needs for piping in this area. ACTION 15: RSS/JP

Water supply for cooling the gearbox (recirculating system) and power demand for the centrifuge (peak power 1.6 MW for around 12 minutes) were discussed. Steady power requirement is around 1.2 MW at 350g. The power requirements are addressed in detail in a questionaire in the Installation Manual. Power surges and outages will be discussed with Reliance (Ohio). An emergency supply is not to be provided; the machine would simply freewheel.

PROGRAMME AND CONTRACTURAL ASPECTS

Acutronic USA will be responsible for Quality Control on the containment structure. Inspection of the building will be by WES Construction Services Division. However the AE firm could do QA

Reference: 25-03-ROM-068 contd.

inspection if Acutronic chose. Johnson Macadam confirmed that they can readily provide 'periodic' site inspection if required (this to be discussed with Acutronic). WES will perform a Davis Bacon inspection on wages.

The building design proposal will be supplied by Johnson Macadam within the week for audit. Acutronic USA will provide copies for WES and DCAA.

The construction schedule will begin in May (prior to the completion of the design). The construction proposal will therefore be phased to accommodate this (including phasing of costs).

The structural contractor would be expected to be on site by mid-July 1993.

Installation will begin in September 1994 (transportation having taken place during July and August). Acceptance planned for February 1995 (allowing one month float).

Contractural documents should reflect that 30 days prior to any concrete being poured in the walls a detailed plan for the verification of forms and shutters will be provided by Acutronic to the Government for a two week comment period (not binding to Acutronic).

The funding for construction will be over two fiscal years. This will be worked out by iteration following the initial phased estimate.

A meeting will be held in Paris shortly to review interfaces between Acutronic and ANS&A and to agree ANS&A's activities in France during the fabrication phase. ACTION 16: RSS/JP

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-069
Present:	RSS, RHL, W Marcuson	Date:	11 February 93
		Time:	am
		Prepared:	RSS
		Notes:	WES
Subject:	Centrifuge programme		

Marketing

A marketing plan is to be prepared by RSS, RHL and GH for WM to review. This will include target clients and a visit schedule.

Staffing

Staffing of the centrifuge is being considered to provide expertise in the areas of:

1. Marketing
2. Design of models
3. Instrumentation
4. Model making
5. Operation of the facility.

The management structure is still to be defined.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-070
Present:	RSS, RHL, P Schroeder, R Lee	Date:	11 February 93
		Time:	am
		Prepared:	RSS
		Notes:	WES Environmental Lab
Subject:	Environmental capabilities		

Appurtenances now under consideration to provide capabilities in environmental field. Environmental Lab would like to do some preliminary tests to identify what would be the preferred solution for appurtenance design. Staff might include:

Tommy Myers
Jim Brannon
Carlos Ruiz.

It was agreed that a visit to Cambridge would be the best way to become familiar with current research activities on the centrifuge in the environmental area.

Key problem areas:

a. Treatability studies for TNT moving in groundwater.
b. Lead shot leaching in groundwater.
c. Surface runoff using filter berms.
d. Longterm performance of artificial soil made from biomixes such as lime sludge, sewage sludge (biosolids), dredging materials mixed to make a blend for golf courses, turf, wetland creation etc. Concern over what will leach out of these materials over time.
e. Coastal erosion processes.

RSS suggested that individuals might consider MPhil programme at Cambridge for training/project applications. RSS to send details of current work and to discuss opportunities with C Savvidou.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-071
Present:	RSS, J-FC, JP, AFA	Date:	11 March 1993
		Time:	10.30 am
		Prepared:	RSS
		Notes:	Meeting at Les Clayes
Subject:	Centrifuge progress		

Containment Structure

The design and layout of the building were discussed following the meeting in Vicksburg with Johnson Macadam. A further copy of the Johnson Macadam Preliminary Design Report should be requested from WES for J-FC. The circulation of information, and particularly key reports, will be discussed by RSS with RHL at the next opportunity.

Transportation system

An integrated transportation system should be provided covering both buildings and the loading of packages onto the centrifuge. Experience at LCPC indicates that delicate handling of large packages by crane is extremely difficult and it is preferable to push them on a floor based system. Airpads are now used routinely for easy transport of heavy packages. Adopting such a system would enable the crane along the overhead walkway and the crane in the Prep Room to be dispensed with. Similarly a floor mounted cantilever crane in the Prep Room would be considerably cheaper than providing lifting points in the ceiling or a full overhead crane facility.

The large drop (approximately 6m) between the upper level walkway and the Prep Room floor would be best accommodated using a hydraulic lift. This would provide the smoothest method of lowering packages on their floor transporters from the upper to the lower level. A short travel crane could also be used to lower packages from the high level to the low level.

Loading of the centrifuge

The transport system must be continuous and provide for the easy loading of the centrifuge. The design of the centrifuge, with the increased diameter of the booms near the ends, will make loading by forklift extremely difficult except perhaps for very small packages. However an airpad transporter could be easily docked with the centrifuge platform and packages pushed from the transporter onto the swinging platform. If rubber mats are used then an additional steel sheet can be placed on top of the rubber to provide a lower friction sliding surface for the model.

Concrete docks could be provided at very low cost in the Prep Room for 'parking' packages.

Transport system: recommendations

It was agreed that a floor mounted system would be the most effective and appropriate means of moving the large WES packages and of loading them onto the centrifuge. JP will investigate the cost implications of installing a hydraulic lift instead of the walkway crane and Prep Room crane.

JP will incorporate docking points on the swinging platform for the transporter.

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Reference: 25-03-ROM-071 contd.

Camera facilities

It was agreed that a camera slot in the ceiling was unnecessary and should be dispensed with. Such a fixed camera can only be used at low g anyway because it would involve flying without the aerodynamic shroud door and in this case a camera could be mounted on board. Furthermore experience shows that making the underside of the unit flush and maintaining it flush in the area of maximum air pressure is difficult. If it was considered necessary in future a hole could be drilled in the ceiling to provide a camera position.

Power supplies

A transformer will be provided by ANS&A on board for use with user equipment. Acutronic's power rings comprise 3 live, 1 neutral and 1 ground line. Drawings of the slip ring stack are in the Acutronic mechanical design book. Note that there are 27 spare rings: the majority of which will become available to the user after Acutronic have completed commissioning.

Termination and routing of services onto platform

It was agreed that the best position for the services would be on the outside of the booms, with power and hydraulic services mounted in a channel on the leading side and signal lines mounted on the trailing side. This will keep the full headroom space available for the user and will be easier to install and service. It will also be considerably less obtrusive than routing the services from between the booms over the hinge to the outside as had been previously thought necessary. The hydraulic and power lines will be terminated in a panel at the end of the boom, from where they can be easily connected to the top of a user package. Signal lines will be routed over the hinge and down the straps to termination panels inside the rear shroud at the level of the platform slab.

Acutronic will prepare proposals to supply and fit these services, including cabling and piping, as an alternative to providing cable trays inbetween the booms (as previously discussed). The cabling will simply extend the present slip ring services along the booms to the termination panels. Sufficient cable will be provided for the user to reroute the cables at the slip ring stack into a future on board digital data aquisition system.

Programme

The latest version of the Acutronic centrifuge programme was received.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-071
Present:	RSS, J-FC, JP, AFA	Date:	11 March 1993
		Time:	10.30 am
		Prepared:	RSS
		Notes:	Meeting at Les Clayes
Subject:	Centrifuge progress		

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JP will incorporate docking points on the swinging platform for the transporter.

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Reference: 25-03-ROM-071 contd.

Camera facilities

It was agreed that a camera slot in the ceiling was unnecessary and should be dispensed with. Such a fixed camera can only be used at low g anyway because it would involve flying without the aerodynamic shroud door and in this case a camera could be mounted on board. Furthermore experience shows that making the underside of the unit flush and maintaining it flush in the area of maximum air pressure is difficult. If it was considered necessary in future a hole could be drilled in the ceiling to provide a camera position.

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Programme

The latest version of the Acutronic centrifuge programme was received.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-072
Present:	RSS, RHL	Date:	6 April 1993
		Time:	9 am
		Prepared:	RSS
		Notes:	Meeting at Vicksburg
Subject:	Centrifuge		

Containment Structure

Progress was satisfactory. Further soil samples taken independently supported the recommendation by Johnson-Macadam that piles were not necessary. Differential settlement was estimated to be up to 0.5 - 0.75", which would be acceptable to Acutronic France. The small additional access door into the chamber would not be necessary.

Slab analysis

The ASCII format file had been received from Acutronic. A copy was given to RSS to assess. JP had been asked to consider the cost of providing a user friendly version of ANSYS for centrifuge engineers to use.

Cabling and pipework on the arm

JP would be making a proposal for the additional cabling and pipework on the arm as discussed at the meeting with AFA in France on 11 March (25-03-ROM-071).

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-073
Present:	RSS, RHL, Don Yule	Date:	6 April 1993
		Time:	10 am
		Prepared:	RSS
		Notes:	Meeting at Vicksburg
Subject:	Environmental/seismic proposal		

Seismic response of hazardous waste containment sites

Four key aspects of this problem were considered to be amenable to centrifuge modelling:

1) Fault rupture on a preexisting landfill (uncoupled from the seismic problem). Modelling of geomembrane/geotextile properties would need to be carefully considered.

2) Liquefaction/softening of soil with high excess pore pressures: effects on membrane or composite barrier (eg. clay/geotextile/gravel, perhaps repeated). Effects on cap (slope stability) or across large sites.

3) Long term behaviour of damaged containment.

4) Behaviour of landfill when a part of a general spreading or large scale shallow slope instability.

The goal of the project might be to validate existing designs, proposed designs and future designs.

The gaps in existing knowledge are in the prediction of the strain field and the dynamic response of the liner system and cap; and in the nature of the dynamic properties of the landfill waste and liner system.

The WES centrifuge advantages include cost, team approach, appurtenances, potential for deep sites, long diffusion periods and large area sites.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-074
Present:	RSS, RHL, Tommy Bevins	Date:	6 April 1993
		Time:	2 pm
		Prepared:	RSS
		Notes:	Meeting at Vicksburg
Subject:	Blast chamber		

Dynamic analysis of blast chamber

Initital results indicate that the thick steel wall acts as a very stiff ring and the maximum deflections of the rubber mat are around the perimeter of the tub. This has been based on an axisymmetric analysis using DYNA2D with appropriate approximate bending stiffness of the slab. Peak displacements of the slab are around 0.5 mm in the centre (including static self weight deflection). This is less than the maximum deflection in the centre under a uniformly distributed load, which is also probably due to the concentrated load under the perimeter walls.

Peak stresses (including self-weight) are estimated at around 100 MPa, using a wall and base thickness of 40 mm.

Further analyses will be carried out to allow for reflected peak dynamic stress wave (presently x 1.0) to be x 2.0 at the wall. 10 gms PETN (around 13 gms TNT) currently being used at mid depth in a 500 mm sample. The sample has been assumed to be a heavy fluid, which is pessimistic, but the influence of the reflected wave is still to be taken into account.

The results are due to be completed within around one week. A further calculatioin will also be run using a 400 mm extension and an 800 mm depth sample at 200 g for comparison.

The DYNA2D data file will be supplied to RSS.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-075
Present:	RSS, RHL	Date:	6 April 1993
		Time:	4 pm
		Prepared:	RSS
		Notes:	Meeting at Vicksburg
Subject:	Transport system		

Transport system

Different transport systems were discussed, including air pads (eg. supplied by Solving Systems), skates and linear bearings. Packages should have legs and lifting screws.

H Voss has identified a lifting scissor jack trolley with several tons capacity at a cost of around $3500. Other systems with higher capacity are being investigated.

The possibility of locating a lifting system in the floor was dicussed in detail. A hydraulic lift adjacent to the platform would have considerable advantages in providing flexibility to lift from a package mounted on a variety of other transport systems alongside the swing from where it could be slid onto the centrifuge platform. RHL will discuss this with Johnson-Macadam and H Voss.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-076
Present:	RSS, RHL	Date:	1 June 1993
		Time:	10 am
		Prepared:	RSS
		Notes:	Meeting at Vicksburg
Subject:	Building plans		

Drawings of the containment structure and preparation room were discussed. The following points were noted:

1.0 Equipment Room Level

1.1 The two air vents in the floor in line with the motor set exit through a single air duct at equipment room level.
1.2 It was not clear how the corner sump drains.
1.3 The stairwell shaft is shown enclosed to the top floor.
1.4 There are steps on either side of the motor over an 18 inch wide service trench.
1.5 The 10 ton platform lift is not shown.
1.6 There are two sealed voids in the floor (11' 6" cube).
1.7 Two walls extend out as far as the foundation for the lift structure; should they not extend under the end wall?

2.0 Chamber Level

2.1 The 10 ton lift was not yet specified. It would probably require several rams for stability.
2.2 A sump (environmental collection pit) is shown outside the building. This should be shown on the equipment room drawing.
2.3 The jib crane should be moved towards the overhead door.
2.4 Four drains are provide in the centrifuge chamber around the central dais.
2.5 A 3 ton four post utility lift has been specified for the high drop; this will need to go flush with the floor.
2.6 No doors are shown in the access from the stairwell to the prep room.
2.7 No drains are shown in the model preparation room.

3.0 Air intake chamber level

3.1 The stairwell is closed to this level, where a handrail protects the opening to the airshaft, opposite the louvres. There should be fans here also.
3.2 The mounts for the fans on the intake are not shown.
3.3 Three removable floor panels are shown: no camera slot.
3.4 A small room is now available with outside access for amplifiers and signal conditioning equipment, approximately 80 square feet.
3.5 The opening to the 3 ton lift is 8 feet wide.
3.6 The covered walkway now extends to the stairwell, with a 12 feet wide walkway (slightly less clear width).

4.0 Roof plan

4.1 Removable roof panels over centrifuge access and air shaft.
4.2 Details of craneage points to support the centrifuge are not shown.
4.3 The roofs over the crane shaft, signal conditioning room and walkway are now all integrated with a high point at 199' elevation, sloping to the north.

5.0 Cross sections

5.1 The chamber wall is shown as 14 inches thick.
5.2 There is an 18 inch wide walkway shown on either side of the motor set; this seems narrow.
5.3 The air ducts are shown as circular.
5.4 The roof sections are also shown as 14 inches thick.
5.5 The trench/walkway does not quite reach the end of the motor pedestal under the central axis.
5.6 The stairwell is shown as 3' 4" wide.
5.7 The lifting points to support the centrifuge are not shown.
5.8 The centrifuge chamber sits on the four corners of the foundation block and overhangs on each side (Fig.1).

Elevations Summary (Fig. 2)

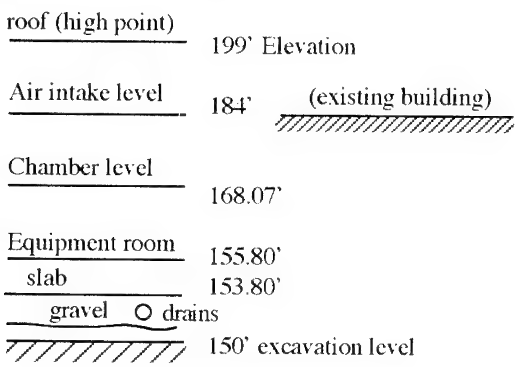

Fig 2

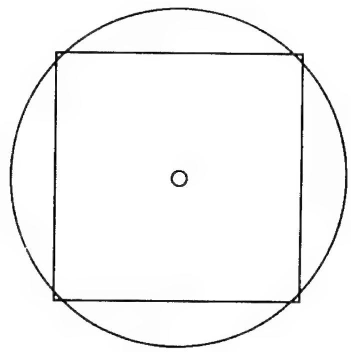

Fig 1

Power supplies

Acutronic USA have confirmed to WES that US standard 3 phase power will be available to the user on board.

Visit by RHL to Europe

Funding had been approved for RHL to visit the UK and Acutronic France. RSS would arrange dates and programme.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-077
Present:	RSS, RHL	Date:	1 June 1993
		Time:	2 pm
		Prepared:	RSS
		Notes:	Meeting at Vicksburg
Subject:	Equipment for FY93		

The specification of circular tubs for high pressure and standard application was discussed.

Differences between the 850 mm diameter and 1000 mm diameter options for high pressure work were noted as follows:

The depth of the equivalent prototype sample can be calculated assuming a certain density in the model and a constant model mass:

350 g model test: analysis of equivalent prototype depth of sample

1000 model mass (kg)		Depth in model chamber: 850 mm tub			1000 mm tub		
Density	Volume (m3)	Model (m)	Field (m)	Field (ft)	Model (m)	Field (m)	Field (ft)
2700	0.370	0.653	228	749	0.472	165	542
2000	0.500	0.881	308	1012	0.637	223	731
1900	0.526	0.928	325	1065	0.670	235	770
1700	0.588	1.037	363	1190	0.749	262	860

It was agreed that the advantages of an 850 mm diameter tub in depth of prototype model and standardisation with other Cambridge equipment, consolidometers, gantries etc. outweighed the small disadvantage of loss of area.

Penetrometer

If budget was available, CIEL should consider designing a moving track for the penetrometer.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-078
Present:	RSS, RHL	Date:	1 June 1993
		Time:	4 pm
		Prepared:	RSS
		Notes:	Meeting at Vicksburg
Subject:	Equipment for FY94 and beyond		

Equipment priorities for FY94 were discussed. RSS proposed outline costs for different groups of appurtenances.

	OUTLINE COST ('000 US$)
COLD REGIONS WORK	120

1. Holding constant temperature, eg 70, 60, 50 degrees or lower;
2. Slow thaw/freeze;
3. Fast freeze;
4. Cyclic freeze/thaw.

Probably seek to accomplish 1. and 2. in FY94. Need to confirm with C.CORE their plans and experience. Objectives 1. and 2. would be necessary for WES operations anyway.

CONSOLIDOMETER	100

A circular tub (850 mm diameter), with hydraulic ram and control system will provide a clay capability; may also require an adaptor for a plane strain box (see below).

DATA AQUISITION II	60

Data aquisition on board, including digital data transmission with on board computers and development of remote monitor.

PLANE STRAIN BOX	120

Rectangular model test box with adaptor for consolidometer apparatus.

TOTAL PROPOSED EQUIPMENT COSTS (FY94)	400

OTHER EQUIPMENT DEVELOPMENT FOR CONSIDERATION IN FY94

The development of an earthquake shaker is regarded as a priority but development and delivery will be required within the same fiscal year.

Equipment and appurtenances which may be developed during FY95 include:

Hydraulic models	Using a recirculating system. ANS&A will consider approximate level of development costs.
Earthquake shaker	High g shaking a priority. Servo-hydraulic systems not considered to be capable of providing shaking above about 100g at present. Other alternatives will need to be considered.
Loading systems	
Environmental liners	ANS&A will consider possible specifications of such equipment based on current knowledge.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-079
Present:	RSS, JN-F, JP	Date:	13 July 1993
		Time:	10 am
		Prepared:	RSS
		Notes:	Meeting at Les Clayes
Subject:	Centrifuge design and fabrication progress		

Current status of project

The detailed design drawings were now complete. Delays to the overall programme meant that little additional work had been carried out over the past few months. Materials had been purchased. The programme was comfortably on schedule for delivery in September 1994. Machining would commence in September 1993. It was agreed that RHL should visit during the last week of September 1993.

Cable Runs

Alternative cable runs were considered from the slip ring stack along the covered walkway to the control building. A route was agreed running through the signal conditioning room and straight along the north side of the covered walkway (under the roof) to the control room (although the roof of the walkway dips to the north, running along the north side would avoid having to cross the walkway twice). Acutronic France would discuss this route with the designers in the USA who would be designing the cableway. ANS&A would run a T from the signal conditioning room over the external door to the 3 ton lift, through the wall into the model preparation room, down to the floor and back again. The length of the route would be approximately 100m without the T drop or ups and downs to the roof of the walkway.

It was noted that only one cableway would be necessary, as power supplies are quite separate and will pass underground under the walkway and down the hill to the 2000 KVA transformer which will provide the power for the centrifuge, the drive systems and fans in the containment structure.

Slip ring stack

The slip ring stack is the same specification as that supplied to Kajima, C.CORE and others and is as specified in Acutronic Proposal PD-9530D. The Airflyte unit was inspected in Acutronic's stores. The wiring is single shielded 1A or 5A, plus 2 coaxial video lines. There is around 3m of wiring at the centrifuge end of the unit, and around 1m at the fixed end.

It was agreed that spare panel mount connectors would be provided but not wired to allow users in future to wire up any spare lines which may be available in the slip ring stack following Acutronic commissioning.

CIEL's proposals to drive most data channels single-ended were discussed. It was agreed that this would require slip ring interface boxes to be mounted at both ends of the stack; rewiring of the connectors on the stack to provide this internally would not be desirable.

Power lines

It was confirmed that US standard high voltage 3 phase power will be available to the user on board through a terminal board (comprising five copper bars) on the central axis. A wiring diagram was received showing the user power take off points. The voltage is likely to be around 440V AC. Each of the power rings is capable of carrying 200A but is limited to 80A to prevent damage to insulators.

Video lines

As with the signal lines, it is expected that video amplifiers will be needed to boost signals before

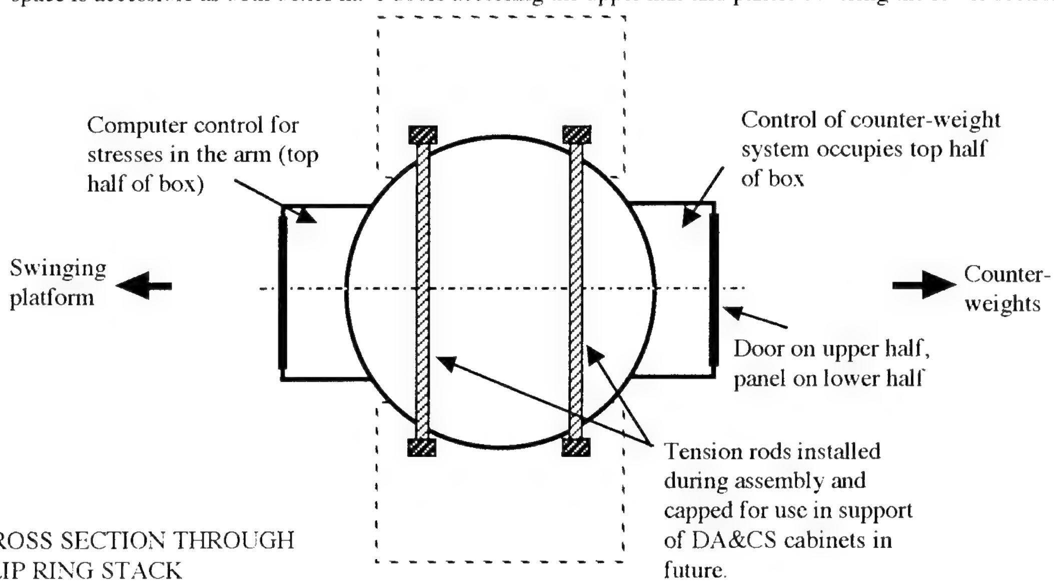
25-03-ROM-079 contd.

transmitting them as far as the control room. These amplifiers are likely to be situated in the signal conditioning room. It was agreed that ideally US standard would be supplied but it was noted that international practice is quite mixed up between 75 ohm and 50 ohm and in practice this makes little difference to the output. The cameras are thought to be 50 ohm, for example, although US standard is 75 ohm. The design of the cabling is not complete as the drawings of the building have only just been received by AFA. CIEL's proposal to standardise on 75 ohm was noted.

Access to the central area around the slip ring stack

It was noted that access to the central box protecting the slip ring stack is limited at present because of the welded design. This space was considered in detail. It was agreed that tension rods could be passed through the central space and used in the future to support cabinets on either side. ANS&A will provide details of a matrix of holes which will be drilled on assembly and used for installing sets of rods.

The two boxes provided by Acutronic are only partially used; in both boxes the lower half is empty. This space is accessible as both boxes have doors accessing the upper half and panels covering the lower section.



CROSS SECTION THROUGH SLIP RING STACK

Arm

Design of cabling and termination panels will commence at the end of September. ANS&A should discuss their requirements at that time with AFA to ensure structural adequacy of termination panel on swing. No further work has been undertaken since the last meeting. ANS&A will confirm whether CIEL or AFA will supply user DA&CS cabling. AFA will supply a price for fitting cable trays external to the booms.

Hydraulic joint

The same unit will be supplied for WES as has been supplied for C.CORE with the exception that C.CORE have had two of the low pressure passages fitted with low temperature seals. The seals on the WES unit can be changed at a later date if required. This would necessitate demounting the unit.

Electrical tests

WES should confirm that no local regulations, for example on electrical testing, will hold up commissioning.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-080
Present:	RSS, ANS, RHL	Date:	19 July 1993
		Time:	9 am
		Prepared:	RSS
		Notes:	Meeting at Vicksburg
Subject:	Earthquake shakers		

Earthquake shakers

Spring shakers are likely to be cheaper and more robust at high gravities but they have disadvantages, particularly the selection of frequency and the complicated design of the cocking and braking systems. A fast clutch now appears to be available for the stored angular momentum system and this concept is now being pursued in Cambridge. It is expected that a SAM system will be constructed for the Cambridge facility over the coming year.

Servohydraulic systems are now being built using Moog valves which can operate at high frequency. These systems will provide shaking capabilities for the majority of centrifuges which operate at less than 100g.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-081
Present:	RSS, ANS, RHL	Date:	19 July 1993
		Time:	9.30 am
		Prepared:	RSS
		Notes:	Meeting at Vicksburg
Subject:	Building plans		

The building site was inspected. Trees had been removed and earth was being excavated.

It was noted that the final design review meeting for the containment structure was due to be held in Vicksburg on 30 July 1993.

Groundworks

The plans for the groundworks and drainage were reviewed. Drainage of the excavation to the north and the stability of the slopes were discussed. Access to the excavation by the contractor for the foundation works was not clear. Possible differential settlements between the main square foundation block and the prep room or other parts of the structure were discussed. Gravel beds under the foundation block will need to be compacted to particular specification suitable for applied loadings.

Rerouting of the storm drains was noted. These had been inspected on site. Extensive rip-rap would be needed at the outlet of the storm drain.

Foundation Level shows non-plastic clayey silts with traces of sand (classified CL on Plasticity Chart). Moisture content around 25-30%. Plasticity index around 15.

The need for a graded filter at the entry to the foundation drain and associated filter fabrics and PVC drains was discussed.

Foundation Level

Access to the voids in the foundation block would be desirable. This could be either from the air shafts or from the centrifuge chamber through hatches in the floor. The foundation loadings should be provided by Johnson Macadam in terms of tons per square foot over the whole area.

The sequence of construction and the foundations for the structural elements was not clear from the available drawings. In some sections undisturbed ground is shown where it would be expected to be fill.

The bearing walls for the lift shaft area need to be clarified. Their foundation and exact length was uncertain. The manifold and location of the air compressor in the motor room was not clear in the drawings. Adequate power supplies (including three phase power) must be available in the basement for the compressor and dryer and other equipment.

Chamber Level

The crane will be positioned midway along one wall. Three phase (480V) will be provided in the north-east corner of the Prep Room. The Data Aquisition system drop position will be in the middle of the north wall.

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25-03-ROM-081 contd.

Provision for water spillage in flight was discussed. Water will escape under the door and will need to be caught in a trench drain outside. Drains are also needed in the Prep Room.

The power unit room could also contain the air compressor and dryer, and the hydraulic power pack. Three phase (480V) also needed in this area.

Cross sections through the chamber do not show the specification for ground treatment and compaction of fill or berms around the containment structure.

Air intake level

The balcony, shown on some drawings, is not needed. The signal conditioning room may be used to house the line drivers. The cableway route was discussed, with reference also to the roof plan.

Control Building

The control building will need to be cleared and finished for use by visitors and for model preparation, instrumentation and data aquisition. Consideration should also be given to installing suspended ceilings, opening new windows and providing office and laboratory accommodation to proper standards.

Power and electrical supplies

The incoming high voltage three phase will need to be transformed to provide user voltages. An isolation transformer will be supplied by ANS&A to achieve this. Equipment which is to be provided under the building contract will be specified by 30 July 1993.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-082
Present:	RSS, ANS, RHL, WM	Date:	19 July 1993
		Time:	10.30 am
		Prepared:	RSS
		Notes:	Meeting at Vicksburg
Subject:	Centrifuge progress		

Collaboration with other research groups

A Memorandum of Understanding with the National Science Foundation is now in place for the use of the facility. Cooperation with academic facilities needs to be established. However it was noted that the size and power of the WES Centrifuge will not be competition for other facilities. Furthermore the WES centrifuge will be the US Government civil engineering facility.

Inauguration

It was proposed that an Inaugural Army Conference should be held at WES in September 1995 to present the new civil engineering research capabilities achieved under the 1988 BAA. Sessions could address capabilities in each field. Around 50 Government invitees could attend, together with around 25 academics and some representation from industry.

Staffing Needs and Management

A meeting of senior leaders on the Station is planned for October 1993 at which ANS&A will present the new capabilities and discuss with the Laboratories their individual needs during the commissioning period.

The Geotech Lab will provide support for the new centre at a level of one mechanical engineer, one soils technician and one electronics technician for some period after handover, to ensure a smooth start to operations.

The management structure of the facility has not yet been finalised.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-083
Present:	RSS, ANS, RHL	Date:	19 July 1993
		Time:	2 pm
		Prepared:	RSS
		Notes:	Meeting at Vicksburg

Subject: Centrifuge progress and appurtenances

Blast Chamber

Two steel rings and four aluminium rings will be provided together with a base plate, gaskets and bolts for assembly. The selection of a rubber mat to isolate the chamber from the centrifuge platform will depend on the dynamic analysis currently being carried out in the Structures Lab.

Data Aquisition System

All parts have been ordered, and negotiations with Acutronic are complete in respect of the interfaces and connectors. Access to spare lines may be possible after commissioning. Acutronic will provide an additional connector (unwired) for future use. In FY94 it is expected that on board digital data aquisition and remote control of computers will be developed.

1200 mm tub and other equipment

The welding of the 1200 mm tub is now complete and progressing to machining and pressure testing. The sand rainer and penetrometer are being assembled.

Acutronic progress

A visit by RHL to inspect the equipment and to meet with Acutronic in France is planned for the week commencing 20 September 1993.

The recent meeting by RSS with Acutronic was discussed. The proposed access to the central slip ring stack area was noted and the concept of using tension rods to carry user cabinets was agreed. WES awaiting cost estimate for fitting of cable trays external to the booms from Acutronic. The cost of supplying cold seals for two of the low pressure lines should be investigated.

WES will need to check whether State or Federal regulations will require testing of electrical components or systems during commissioning.

Equipment 94

Current plans for FY94 are to address temperature control, the consolidometer, a plane strain box and on board data aquisition. The plane strain box will be supplied with a loading actuator. Proposals for equipment development will be submitted in September.

Equipment 95

Inert environmental liners will represent an extension of the thermal control system proposed for FY94. Mechanisms for providing a recirculating supply for hydraulic modelling will be considered. An earthquake shaker will be developed following independent work in Cambridge during FY93.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-084
Present:	RSS, RHL, J Perdriat, H Voss	Date:	20 September 1993
		Time:	12 pm
		Prepared:	RSS
		Notes:	Meeting at Les Clayes
Subject:	Centrifuge progress		

Installation of the Takenaka Centrifuge

Drift has been observed with the Reliance drive for the C.CORE and Takenaka centrifuges. Oscillator problems have been traced to an error in the Reliance calculations and to thermal problems in one capacitor.

The failure of the front shroud of the Takenaka centrifuge was discussed in detail. Initial considerations were that

(a) the camera support may have been too heavy;
(b) there may have been gluing problems in the manufacture;
(c) the FE analysis of the shroud was inadequate.

The Takenaka shroud is considerably larger than the WES shroud because of the larger platform. However the principal loading is self-weight; aerodynamic forces are not taken into account as these are not significant. It was noted that although the size of the WES shroud was smaller, the self-weight would be nearly twice that of the Takenaka centrifuge because of the high g operation.

Experience with the bearing seal (which leaked) will lead to a minor redesign for WES to avoid this problem in future.

WES Containment structure

Two bids had been received, both from companies based in Jackson,, Mississippi. The contract was expected to be placed shortly with the successful bidder and work to commence on site within ten days of signing. The substructure was still expected to be completed before winter. However completion of the building (which should take around nine months) will depend on the funding flow from WES. The outside period quoted to the contractors was fourteen months and termination and delay clauses had been written into the contract. Funds available for the building have been agreed only to December 1993.

WES Centrifuge

Currently on schedule but the delays to the programme during FY93 for funding reasons had led to the postponement of material deliveries to Acutronic. It was noted that this could not be repeated without increased cost and hence the reestablishment of a funding flow from WES by the end of October 1993 was critical to the project.

No funding problems are anticipated at present but Acutronic USA have been requested to preparea plan for possible delay. It was noted that the building funds and centrifuge funds can be interchanged if necessary. The installation and commissioning costs are not expected to be funded until FY95.

A full set of mechanical design drawings will be prepared for submission to WES by 1 October 1993.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-085
Present:	RSS, RHL, J Perdriat, H Voss	Date:	20 September 1993
		Time:	2.30 pm
		Prepared:	RSS
		Notes:	Meeting at Les Clayes
Subject:	Design Review		

Status and Programme

The detailed design drawings were now complete with the exception of some electrical details. Electrical storm had not yet been considered. WES will need to specify the appropriate protection standard.

The programme was reviewed item by item and the status of all components established. An updated programme will be prepared by AFA by 1 October 1993. This will be coordinated with the building programme. Status of the main components is indicated below:

-	Basket assembly 001	Steel for straps has been purchased but not yet machined; no welding or assembly of the slab has taken place (TLM).
	Shrouds	Fabricated at Courtaulds, Rouen; awaiting shipment.
	Bearings	Ordered from SKF but delivery delayed.
-	Arm assembly 002	
	Various	Materials for the counterweights and pistons is at TLM; materials for the boom dividers has been ordered but not yet delivered.
	FME	Booms: steel at Forgemasters in England; machining has started but delivery has been delayed.
	Devaux Werts	Drive box: casting is finished but it has not been delivered to TLM yet for machining.
	Siam	Clamp element: has been delivered to TLM.
	Entran	Strain gauges etc: delayed.
-	Base Assembly 003	
	Bearing	Ordered from SKF: delivery delayed.
	Entreprise Industrielle	Concrete interface to assemble machine: not yet delivered.
	Various	Includes base cruciform: welding complete and inspected, delivered to TLM.
	Slip rings	In stock at Acutronic.
-	Power plant 004	
	Drive	Amplifier at Reliance, motor Leroy Somer not delivered.
	Gear box	Arrived at TLM from Barcelona in August.
	Skid	Delivered with gear box to TLM.
	Various	Couplings etc., delivered to Acutronic.
-	OPTIONS	
	Eraf	Hydraulic power supply for balancing: ordered but not yet delivered.
	Tecmeca	Rotary joint: not yet ordered.
	Various	Cameras and SMS at Acutronic; fans recently defined, to be ordered.

A full set of mechanical design drawings will be prepared for submission to WES by 1 October 1993.

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25-03-ROM-085 contd.

Interfaces with users

Acutronic presented their proposals for passing cables and pipes over the hinges and onto the platform. The cable and pipeways would leave the on-arm trays, located between the booms, before the outer boom divider, pass up to the top of the boom, over the boom divider and down onto the swing support, using the laminated profile of the swing supports. Power and hydraulic lines, on the leading boom, could be terminated partway down the swing support.

On the boom divider a split cone pressure clamp could be used to restrain the cables under high g. Cables would be structurally designed to withstand clamping forces. ANS&A and CIEL would need to suppy information on the shielding required, the connectors and other details (such as the termination panels) and on the hydraulic connectors. It was agreed that Neil Baker would visit Les Clayes during October to finalise electrical connections and hydraulic details. Acutronic USA will prepare an estimate of the costs associated with this work for WES by 30 September 1993. It is anticipated that the likely cost will be around $135K, including $50K for materials.

Power Supplies

The present system (as designed) transforms incoming 660V supply through Acutronic cabinet giving 400V protection for the slip ring power circuit. AFA will need to specify the voltages to be supplied on board for user access. ANS&A will then design an on-board transformer to provide user power at a range of voltages. It was noted that in earlier discussions with AFA it had been agreed that US high voltage 480V three phase would be supplied on board.

Control Room

The layout of the control room is to be determined by WES. The control desk (2.5m high) should be located slightly away from a wall to allow access behind. Cableways from the building to the control room follow the lower side of the walkway. Two trays will be provided, one for Acutronic and one for users.

Hydraulic connections will be supplied between the Prep Room and the basement. Two drain systems, one toxic, one foul, will serve the building. A recessed grate drain will catch fluids escaping under the door.

Acutronic USA will send an updated set of the building drawings to ANS&A.

HV will check on access to the voids in the foundation. It is probable that these will remain sealed.

Shipping and installation

Shipping will be on a US flag ship after boxing from Le Havre to New Orleans. It will then be barged to Vicksburg and trucked to the station. A Jackson crane company have been given details and have provided estimates for the lift. After offloading the centrifuge, the contractor will seal the roof.

The roof is not designed to support a crane. Future large scale maintenance would necessitate removal of the roof. All drive systems and cabinets could be removed through the stairwell if necessary.

Commissioning

The plan for the commissioning tests will probably be based on earlier installations but will need to include dynamic measurements and other instrumentation. It was noted that ANS&A consider this document to be very important and are expecting its delivery on time.

Loading of the centrifuge platform

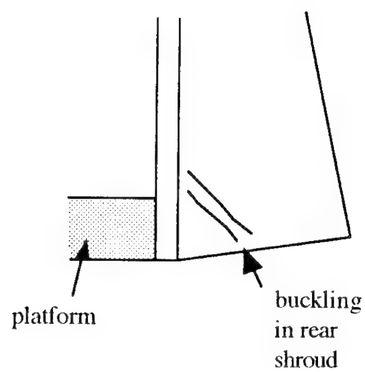
Acutronic's ASCII ANSYS file has been received and WES will seek to convert this for use with ADINA

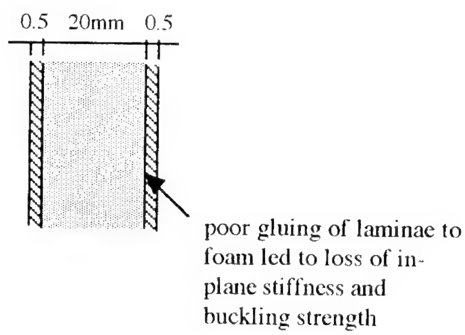
25-03-ROM-085 contd.

or ABACUS on the WES CRAY computer. A final option would be to purchase ANSYS for a PC: probable cost around $10K.

Takenaka shroud failure

The failure of the Takenaka shroud was discussed, and its implications for WES considered carefully. Buckling in the lower walls of the shroud may have led to shear at the upper supports, then rotation outwards and the final explosion when the shroud hit the wall of the chamber.





Pictures of the clean-up and inspection of the Takenaka centrifuge were inspected.

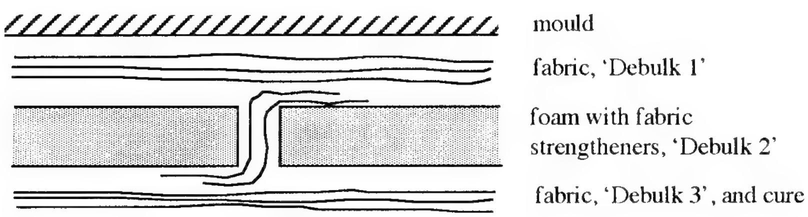
RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-086
Present:	RSS, RHL, JP, HV, AFA	Date:	21 September 1993
		Time:	10 am
		Prepared:	RSS
		Notes:	Meeting at Courtaulds, Rouen
Subject:	Fabrication of shroud		

A visit was made to Courtaulds plant near Rouen to inspect the WES shroud and the repairs being carried out to the Takenaka shroud. The front shroud for WES was not available for inspection.

The process of fabrication was described and the moulds inspected. On inspection it was not obvious that the failure of the Takenaka shroud was caused solely by poor fabrication. It is more likely that it was due to poor design, compounded by sloppy fabrication.

Samples of the foam core and impregnated fabric were receive. The basic fabrication process is as follows:



This process, with the exception of the fabric strengtheners which were added for the WES shroud, was identical for WES and Takenaka.

It was agreed that RSS would visit Courtaulds in the UK to discuss their FE analysis of the shroud, following a request by Acutronic France.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-087
Present:	RSS, RHL, JP, HV	Date:	21 September 1993
		Time:	2 pm
		Prepared:	RSS
		Notes:	Meeting at Les Clayes
Subject:	Centrifuge progress		

Further discussions were held on cabling and piping options over the hinge; it was concluded that Acutronic would need to consider the different options carefully and that this would probably necessitate making a model of the hinge.

The contract for the building construction had not been signed by the contractor, who was now questioning their bid before signing the notice of award. Construction is not expected to start before the second week of October. The question of the specification of the gravel compaction was raised and the importance of monitoring quality emphasised.

Extracts from the ANSYS manual were received, together with drawings of the rotary contact assembly and extracts from the Courtaulds reports on the analysis of the 684 and 685 shroud.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-088
Present:	RSS, RHL, A Curtis	Date:	22 September 1993
		Time:	10.30 am
		Prepared:	RSS
		Notes:	Meeting at NAB Ltd, Biggleswade
Subject:	Inspection of equipment		

The steel blast chamber and base, and 1.2 m diameter tub with extension and pressure lid were inspected at NAB's workshops in Biggleswade. The equipment was reviewed, together with attachments (hydraulic rams, bolts and ancillary equipment) and accepted as meeting the contractural requirements.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-089
Present:	RSS, RHL, ANS, N Baker	Date:	22 September 1993
		Time:	2 pm
		Prepared:	RSS
		Notes:	Meeting at Cambridge
Subject:	Centrifuge progress		

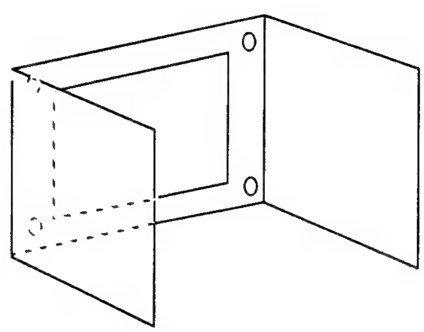
Appurtenances

Equipment comprising the 24 channel data aquisition system and penetrometer (with drive) system were inspected and accepted as meeting the contractural requirements. The use of the equipment was demonstrated; the trunk wiring interface boxes and control systems were demonstrated.

All equipment is to be crated and shipped on request from the US Navy Contracting Office.

Centrifuge interfaces

Acutronic's proposals for cable and pipeways to run from trays between the booms, over the hinges and onto the swing, were considered. It was agreed that this was not necessary and that a user designed framework (such as below) fitting inside and outside the outer boom divider will provide support for termination panels and user fittings. RSS will discuss this concept with Acutronic and request clearance holes to be provided in the boom divider.



The design of the central arm services should include balancing instrumentation; pressure panels, for example, can provide 'nul' measurement when in balance. Central arm services should be integrated in France with the data aquisition systems. The ANS&A data aquisition (stand-alone) system should be proposed to monitor instrumentation during commissioning.

The commissioning test plan will be critically reviewed to ensure that there is an adequate distribution of instrumentation and appropriate loadings. Once the machine has been tested and handed over the central-arm services will be attached and user commissioning will commence.

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25-03-ROM-089 Contd.

A letter should be sent to Acutronic noting the following key points:

(a) the redesign of the shroud following the accident at Takenaka, recently reported to us;
(b) the need for predicted performance during commissioning: deflections, strains etc, will be required under the commissioning plan for components designed by Acutronic or its subcontractors;
(c) the need for the completion of the volume of calculations for the centrifuge, so that these predictions can be made;
(d) that proposals for loading during commissioning will need to include flexible (ie. distributed) loads;
(e) that the delivery date for the commissioning plan is now approaching rapidly.

The failure of the Takenaka shroud was discussed in some detail. Concern was particularly expressed over the possibility of in-plane buckling due to small wavelength "creasing" of the outer skin at the joints in the foam core. ANS&A will discuss the design approach with Courtaulds, but the inadequacy of this material may require extensive rethinking by Acutronic.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-090
Present:	RSS, RHL, ANS, CS,	Date:	14 October 1993
	Environmental Laboratory,	Time:	9 am
	Geotechnical Laboratory	Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Environmental capabilities		

Dr Savvidou discussed the role of the centrifuge in modelling environmental and transport processes to investigate mechanisms, to carry out design studies and to check analyses in a parametric or specific approach. Site specific studies are not yet considered to be practical.

The relationships governing mass transfer, heat transfer and contaminant transport were described in relation to the scaling laws needed to interpret centrifuge model test data. Scaling errors caused by difficulties with reproducing Reynolds Number or the Peclet Number were discussed.

CS then presented examples of centrifuge model tests in the following areas:

(a) heat transfer processes caused by the burial of hot cannisters in the sea bed;
(b) combined heat, pore fluid and contaminant problems caused by the emission of sodium chloride from a hot, buried, porous pipe;
(c) clean-up of contaminated land;
(d) density-driven flow from a landfill.

She concluded that:

(i) accelerated physical modelling of environmental problems has been successful;
(ii) centrifuge modelling is essential for studying density driven flows;
(iii) centrifuge modelling provides an opportunity for validating numerical modelling approaches.

A number of questions were raised on the scaling of chemical reactions (including gas generation), the use of alternative or similar soils, the modelling of heterogeneities, the modelling of microbiological processes, in-flight sampling and the modelling of dredged disposal.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-091
Present:	RSS, RHL, ANS, CS,	Date:	14 October 1993
	Environmental Laboratory	Time:	3 pm
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Development of capabilities		

The meeting was arranged to discuss potential areas of collaboration and likely projects in the environmental area which could lead to a demonstration test during FY95.

Typical projects in the Environmental Laboratory which might be able to exploit a centrifuge capability include:

(a) leachate from upland sites, particularly the behaviour of subaqueous cappings (on riverbeds). Field tests have involved measurement of contaminant migration (metals and PCBs) over 18 months;
(b) movement of TNT and other groundwater contaminants;
(c) consolidation of wetlands in the presence of lateral flows.

A visit from the EL to Cambridge this year is unlikely.

Sampling in flight was considered to be important. The collection of discrete samples would be very useful; equipment to achieve this needs to be designed and manufactured, perhaps in FY95.

It was noted that centrifuge work in EL is routine for separation of materials. Samples of 500 ml maximum may be tested at speeds of 6500 - 12000 g.

The problem of wetlands consolidation is likely to be the initial EL project. Varying the water table will be significant. Hydraulic placing of the fill at initial void ratios of around 9, decreasing to 5 or 6 and finally to around 1.5. Funding would be likely.

Subaqueous capping involving the diffusion of contaminants through a cap is a second problem of great interest. In the field the problem concerns selecting the appropriate thickness of the cap, given the likely contaminants are PCBs or heavy metals. The short term release problem due to the consolidation of the dredged material could clearly be addressed in the centrifuge but the long term problem of diffusive transport may be less amenable to modelling. Similarly in-situ placing of dredged material and its capping are both problems of interest. Funding may be possible.

Groundwater. Multi-phase flow in porous media and the effects of heterogeneities is a particularly challenging area, related to clean-up, which is very significant. The formation of 'fingers' and similar instabilities needs careful consideration in scaling.

With preferential flow in macroscopic pores, limitations will be likely on the Reynolds number and the use of coarse grained materials. It was noted that fluids and materials can be changed and experience has been gained in other areas, but this has not yet been tackled in the environmental area.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-092
Present:	RSS, RHL, ANS, CS, WM	Date:	14 October 1993
		Time:	4.30 pm
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Centrifuge programme		

Acutronic

The funding flow had been recently signed off and was expected to recommence in a few days.

Collaboration with other Laboratories

Positive signs were emerging from most of the other Corps Laboratories of a growing interest in the new capabilities that were being discussed for the centrifuge. Several Labs were already engaged in centrifuge modelling. Both Structures Lab and Geotech Lab are conducting tests at Colorado. These experiments will be likely to be transferred to WES ultimately.

C.CORE is seeking collaboration with WES. This could provide useful training experience and early testing. R Phillips is expected to be a part of the ANS&A commissioning team.

Training centrifuge

A small Schaevitz training centrifuge has now been acquired from Government surplus and will be based in the control building. This facility will be used for early experiments and training and will be integrated into the ANS&A Quality Assurance activities, making use of the new mobile data aquisition system now in shipment.

Marketing

A marketing strategy and plan needs to be developed.

Earthquake actuator

The approach being proposed to develop a high g shaker for WES was discussed, based on mechanical actuation using parallel development work ongoing at Cambridge University. A final decision on the form of actuation will be taken next year in case new developments emerge in the servo-hydraulic area.

Groundwater studies in the Geotech Lab

It was noted that James May, Bill Murphy and Paul Miller, all based in the Geotech Lab, are closely involved in the groundwater programme.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-093
Present:	RSS, RHL, ANS, Centrifuge Committee	Date:	15 October 1993
		Time:	9.00 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Centrifuge Committee		

Training Centrifuge

Paul Gilbert described the new Schaevitz training centrifuge recently acquired from Government surplus which was now in place in the control building. It has a radius of 2 feet and a 50 lb payload capacity. Maximum g level is xg.

Centrifuge status

The present status of the centrifuge design and fabrication was described and the recent visits by RHL and RSS in France and the UK to review progress with Acutronic and to inspect the shroud and appurtenances were discussed.

Appurtenances

The 1200 mm tub, blast chamber, penetrometer and data aquisition system (now in shipment) were presented and future requirements for FY94 and FY95 discussed.

Demonstration tests

It was noted that demonstration tests for each of the Laboratories were now being drawn up; further meetings with some Laboratories (particularly Coastal and Hydraulics) would be necessary to finalise plans for the development of capabilities relevant to their field of research.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-094
Present:	RSS, RHL, ANS, Environmental Laboratory	Date:	15 October 1993
		Time:	10.30 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Demonstration tests		

Three possible projects were discussed in detail.

Wetlands

Richard (Dick) Lee described the simulation of wetland creation and restoration in a coastal environment. The impact of the water surface on the consolidation of very loose soils in the presence of a lateral flow is the main uncertainty. This would be readily addressed by centrifuge modelling.

Capping Stability

Mike Palermo outlined the problem of design of caps to cope with short term stability, long term stability and erodability. Difficulties were perceived in the accurate modelling of multi-layer materials, different sediment layers or geotextiles, even at low gravities.

Multiphase flow in saturated/unsaturated media

The centrifuge is used already to characterise certain properties (eg wettability) of samples. However although this is a critical area of interest, it is also the most challenging for centrifuge modelling.

It was concluded that the capping experiment would be most likely to form the basis of a demonstration experiment. The wetlands consolidation may be undertaken as a precursor to the cap experiment.

Paul Shroeder and Dick Lee will coordinate EL appurtenance requirements. ANS&A will consider an outline scheme for appurtenance design. ANS&A will provide support in the preparation of proposals for project funding if required.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-095
Present:	RSS, RHL, K Davis	Date:	15 October 1993
		Time:	2 pm
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Demonstration tests		

Two projects were discussed which could form the basis of demonstration experiments.

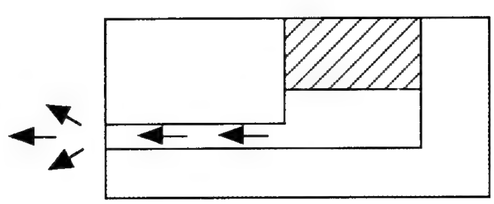
Stability of pile supported foundations in wet soils (Geomechanics Division)

These experiments comprise non-nuclear charges in saturated clay or sands detonating near pile foundations. It was noted that RSS had completed a series of similar experiments in 1986 for the AFWL. Field tests have been done in clay. Centrifuge tests are presently being undertaken at Colorado by John Ehrgott of the Structures Lab.

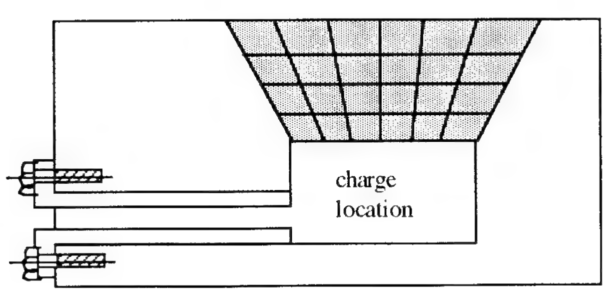
Explosive storage safety

A preferred project may be the modelling of the safety of rock magazines (known as 'shotgun' magazines) based on the British Navy design. This experiment would use a steel or aluminium 'rock' formation with a charge placed in a simulated cavern. High speed photography would be used to study the relationship between entrance tunnel diameter and cover depth. Small scale model tests have been carried out in the UK at 1g and a 1/2 scale field experiment was carried out in the US. These have not proved satisfactory in validating the computer model developed for this problem as significant errors were found in comparing the 1g and field tests.

The proposed model would be tested at 1, 20, 80 and 300 g using a fixed linear scale of 1/100 and a fixed charge mass of 100 gms. The steel block model would be approximately 700 x 500 x 400 mm high.



Critical thickness to prevent release is of interest; should heave rather than eject overburden.



Possible model layout, using loose metal blocks and an adjustable vent diameter.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-096
Present:	RSS, RHL, WM	Date:	15 October 1993
		Time:	3 pm
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Key points arising		

(1) The centrifuge pit will be inspected weekly. The silt fences will be mended and the drainage repaired.

(2) A memo will be circulated on the Station describing the new Schaevitz Training Centrifuge.

(3) The possibility of acquiring a larger Training Centrifuge will be investigated carefully.

(4) The manager of the Inaugural Conference for September 1995 will be selected by 1 November 1993.

(5) The management structure and staffing of the centrifuge centre has yet to be decided.

(6) The training needs and travel requirements for FY94 need to be finalised.

(7) Further meetings are needed with certain of the Laboratories to assist in identifying their appurtenance requirements and a demonstration experiment.

(8) Contact will be established with C.CORE and between C.CORE and CRREL.

(9) The funding flow to Acutronic has been reestablished.

(10) Marketing opportunities to present the new WES capabilities will be identified and a plan developed.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-097
Present:	RSS, RHL, Centrifuge Coordinating Committee	Date:	6 December 1993
		Time:	9 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Development of capabilities		

Training and programme

The status of the centrifuge programme was discussed. The pit for the containment structure is presently under construction and the contractor is awaiting the arrival of the crane. Formwork for the concrete foundation is being fabricated.

A small, 3ft radius, 100lb payload training centrifuge has been acquired for the WES and will be based in the centrifuge control building. This Schaevitz centrifuge has a top speed of 400 rpm, giving approximately 150g maximum at a typical package radius. It is expected that this facility will provide valuable experience in model testing techniques and instrumentation.

A training schedule will be developed over the coming year and implemented by Paul Gilbert of Geotech Laboratory, in conjunction with ANS&A, as soon as the facility has been integrated into the centre.

Coordinating Committee

The membership of the Committee is likely to evolve. PI's on the Station need to be advised and enthused. Sponsors can then be briefed on the new capabilities.

An inaugural conference in the Fall of 1995 will provide a showcase for the new capabilities at WES. Each Lab will need to prepare a list of invitees and should be prepared to make presentations and to submit papers. The status of individual Labs was then discussed in turn.

Hydraulics Lab

Joint discussions are to be held between Hydraulics and Geotech Lab to discuss centrifuge applications on the groundwater programme. There is still considerable interest in a flume experiment and in the development of a recirculating flow system.

Information Technology Lab

An internal review to be held by Geotech Lab in January will involve ITL because of the overlap in research interests.

Environmental Lab

Three areas in which the Evironmental Lab has interests which may be relevant to centrifuge modelling are: the groundwater research programme, reservoir quality (a combined physical model of temperature and contaminants) and the use of wetlands.

Research into the performance of wetlands may be a priority for early centrifuge model tests. In the field sewage from secondary treatment plants is discharged into natural wetlands in place of tertiary treatment. Concern exists over the level of loading and the life of the process before the wetland is overloaded.

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Ref: 25-03-ROM-097 contd.

Variations in wetland type will affect their assimilation capacity. Oxidised wetlands, for example, will treat nitrates but not copper. Wetlands are typically one to two feet deep and many acres in size. Typical experiments carried out at present comprise strips of soil 6-8 inches thick and around 15 feet long; outflow from the strip may start to be seen after about one hour, this reducing to 15 to 30 minutes once the material is fully saturated.

A wetlands model would ideally use natural soil; these are generally fine textured silty clay soils with a high (10%) organic content. A typical problem of interest would be to study the adsorption of metal cations from highly soluble nitrates to organic complexes in the system leading to the development of break-through curves. Similarly, wet and dry cycling in wetlands would be of interest in wetlands that periodically dry out.

Other examples include:

a) the creation of wetlands by consolidation of dredged disposal, perhaps with a ten year life;
b) the performance of a CDF (Confined Disposal Facility) - for example how to drain water from perhaps 18 feet of material confined in a harbour;
c) the long term consequences of tidal cycles or intermittent flow on wetlands;
d) concern over the long term safety of using sewage sludge for wetland creation;
e) the potential for the use of organics to capture or slow up TNT contaminants in the ground.

RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-098
Present:	RSS, RHL	Date:	6 December 1993
		Time:	12 pm
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Centrifuge programme		

The new programme, received by fax from Acutronic USA, showed a handover date of May 15, 1995. The implications of this new date for the time available for the commissioning of capabilities by ANS&A during 1995 and for the timing of the inaugural conference were discussed.

The pit for the containment building was inspected. The contractor were assembling shuttering for the first concrete pours. The access stairway and gravel working platform had been built. Slope failures around the side of the pit had caused contamination of the gravel bed in some places. These were to be re-excavated. The square base for the foundation pad had been marked out.

Work had been proceeding on the Schaevitz centrifuge. Initial commissioning runs had been carried out.

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RECORD OF MEETING

Project:	WES	Reference:	25-03-ROM-099
Present:	RSS, RHL, Coastal Lab	Date:	7 December 1993
		Time:	10 am
		Prepared:	RSS
		Notes:	Meeting at WES
Subject:	Coastal capabilities		

A detailed presentation on the centrifuge development and current status of the programme was made to a meeting of PI's and other researchers at the Coastal Lab. Different demonstration tests were discussed, including explosions in shallow harbours and the use and development of wave generators under the project.

Concern was raised over the range of modelling scales over which Froude numbers and Reynolds numbers could be identically reproduced. It was noted that for a gravity scale N_g, linear scale N_L and viscosity scale N_μ,

$$N_g N_L^3 = N_\mu^2$$

for correct similitude of Froude number and Reynolds number. As $N_g = 1/n$, then for example if $n = 350$ and $N_\mu = \sqrt{n}$, then $N_\mu = 18$ and $N_L = 50$.

Thus significant linear scales can be achieved for modest increases in fluid viscosity even if similitude for both Froude and Reynolds numbers is required. It was noted that in many examples it is quite sufficient to maintain only one or other of these two parameters "constant". For modelling explosion waves, for example, only inertial effects are significant and hence Froude modelling alone is adequate.

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